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The Magical Effects of the Magic Lantern

The magical effects which owe their origin to the magic lantern, are those which will chiefly occupy our attention; and it will be found that the position of this ingenious instrument in the popular estimation is very far below that which it deserves to occupy. In fact, all those appearances which so much perplex, surprise, or please us in exhibitions of this kind are entirely due to the various ingenious contrivances appended to, or in connection with, this instrument….. Essentially it consists in its improved form of a powerful source of light, of two double convex lenses which concentrate the rays, and direct them upon the picture placed in front of them; and of two other lenses which concentrate the rays after they have passed through the picture, and direct them on the disk where the image is beheld by the spectators.

"Optical Magic of Our Age," *Littell's Living Age*, November 17, 1849, p. 319.

Once again, the cycle of the seasons has moved ahead of my ability to get this issue of the *Gazette* ready. Although it is the Spring issue, spring has long since come and gone, as have the eggs of the Veery depicted on the cover. The tardiness of the issue is due to series of unfortunate events, unexpected summer department head duties, and, just as I was nearly finished with the issue, Hurricane Irene, which knocked out our power and water for five days. After stumbling around the house as if in a bat cave, I finally emerged to get this issue finished.

Nearly the whole issue is occupied by a very long and detailed article by John Davidson on the history of magic lantern optics and lens-making from Biblical times to the present (see image on the back cover). He provides some technical appendices for the mathematically inclined, but even if you don't read those, his article provides a very useful reference that clearly explains the progress, or lack of progress, in lens design over several centuries. His article gives us a much better understanding of how early magic lanterns worked, and the limitations on the quality of images they could project, as well as the perfection of the lantern lens system in the 19th century.

It may be of interest to future researchers to know that nearly all of the old texts on optics cited in John's article are now available free on Google Books in digital form, at least in the United States. Now anyone can access Kircher's first illustrations of the magic lantern, or Smith's *Opticks* of 1738, with a few keystrokes. This material can be easily accessed by going to the Magic Lantern Research Group: https://www.zotero.org/groups/magic_lantern_research_group/items/collection. This site provides links to hundreds of books on magic lanterns from the 17th to the 20th centuries [for some reason, the latest version of **Zotero**, which hosts this site, does not have live links anymore, but you can copy the URL for a particular book and paste it into a new browser window and go directly to the book, usually to the exact page that contains magic lantern material].

This issue is rounded out by a short Research Page with an eclectic summary of scholarly articles related to magic lanterns, many in obscure academic journals that most of us have never heard of, plus a couple of reviews of new magic lantern books. What is encouraging is that academic scholars are beginning to take serious notice of the magic lantern as an important cultural phenomenon, with links to the history of science, cinema, literature, and other fields. Unfortunately, many of these scholars still seem ignorant of the valuable material published by the two magic lantern societies, although some awareness of this work is creeping into the literature. The posting of all back issues of the *Magic Lantern Gazette* and its predecessors on the San Diego State University Special Collections webpage should help to make these valuable contributions more visible to scholars. One can only hope that back issues of *The New Magic Lantern Journal* eventually will find their way onto the internet.

I hope to have the next issue out in a much shorter time frame. I already have a feature article from one of our members ready to format, and I have an unusually large cache of academic papers for the Research Page, plus several important new books to review. At the very least the Summer issue will be out before the snow flies.

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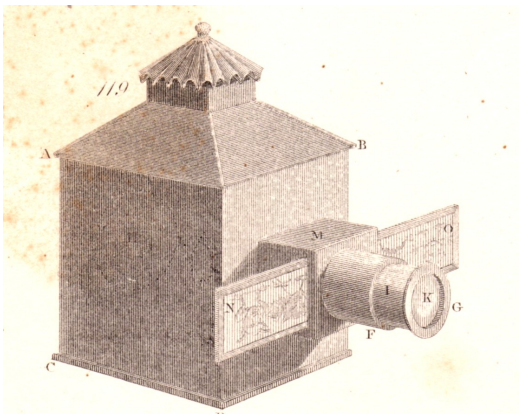

Magic Lantern Optics: Their History and Development 300 B.C. to 2004 A.D.

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Although much has been written about the magic lantern, the subject of its optical construction with regards to optical science has been neglected. For example the 18th century claim of the projection of images on clouds of smoke has been mentioned by many authors, but it is a feat that is quite impossible, because for a lens to project an image, it must project it on to a plane surface at a well defined distance; such a condition is not met in a smoke cloud. This article outlines the history of the magic lantern in the context of the history of optics.

Because all magic lanterns possess at least an objective lens and nearly all a condenser, I shall start by reviewing briefly what is known about the development of lenses before considering their use in the magic lantern. Arthur Koestler pointed out in his work *The Act of Creation*[1] that there is a certain "ripeness" for discovery and invention. Over and over again, the history of science and technology reveals that a given idea occurs at more or less the same time to more than one individual. In 1922, Ogborn and Thomas documented about 150 examples of these phenomena. Perhaps the most striking and well documented example is that of Alexander Graham Bell and the invention of the telephone. Very few are aware that Elisha Gray submitted a similar patent application ***on the very same day*** as Bell for the same invention.[2] The rival claims for the invention of the telephone were submitted to the patent office only 2 hours apart, and one scholar maintains that there was a clerical error and that Gray should have received the patent.[3] It may be that both inventors were preempted by Philipp Reis (1834-1874), who supposedly had a working telephone as early as 1860 in Germany.[4] Merton in 1961 came to the conclusion that simultaneous discovery was the rule rather than the exception.[5] Hence, it is not surprising that the invention of lenses and all other optical instruments, including the magic lantern, are shrouded in doubt and uncertainty.

There are in museums, stones, more or less transparent, with convex and concave surfaces, which could have served as lenses and date back some 3000 years. Pliny stated that such stones could converge sun light and be used as burning glasses to start fires (Book 37, chapt. 2).[6] However, the history of the science of optics properly begins with the writing of Euclid about 300 B.C. with the work *Optics and Catoptrices*. Although Euclid's authorship of *Optics* is not questioned, there is doubt about the authorship of *Catoptrices.*[7] This latter work, sometimes referred to as *Specularia*, concerns the properties of mirrors. The author discussed the rectilinear propagation of light, the property of a plane or flat mirror of equal angles of reflection and incidence, and the ability of a concave mirror to bring light rays to a focus and ignite combustibles. Vision, as explained in Euclid's optics was caused by "visual rays" which proceeded in straight lines from the eye! This, along with the dislike of the Greeks for experimental investigation resulted in no further progress until the time of Ptolemy some 500 years later.

Ptolemy investigated and published experimental results on refraction, or the observation that upon entering a denser medium, such as glass or water, light is bent towards the normal to the point of incidence of the incoming light ray (Fig. 1a). These results took the form of a table of angles of incidence and the corresponding angles of refraction. A classic demonstration of this effect is to place a coin in a teacup and then move the cup on a table so the coin just cannot be seen in the bottom of the cup. Keeping the observer's head and the cup in the same position and filling the cup with water will make the coin visible. Similarly, a straight stick thrust into water at an angle will appear bent or crooked when viewed from the side at a low angle. W.C. Fields, the American film comic, made reference to this fact when casting aspersions against water as a beverage in comparison to water mixed with alcohol, made a proper drink. However, he should have investigated further, as we shall soon see. The fact that for a given system such as air/glass or air /water, that the ratios of the sines of the angles of incidence to those of refraction is a constant, known today as the refractive index, would not come until the work of Willebrord Snellius (1580–1626) in 1621, work that was generally unknown until published by Descartes in 1637.[8] The refractive index of vacuum/air is 1.0003, or unity for all practical purposes, and that of air/water 1.3333. However that of air/ethanol is 1.3611, so a mixture of

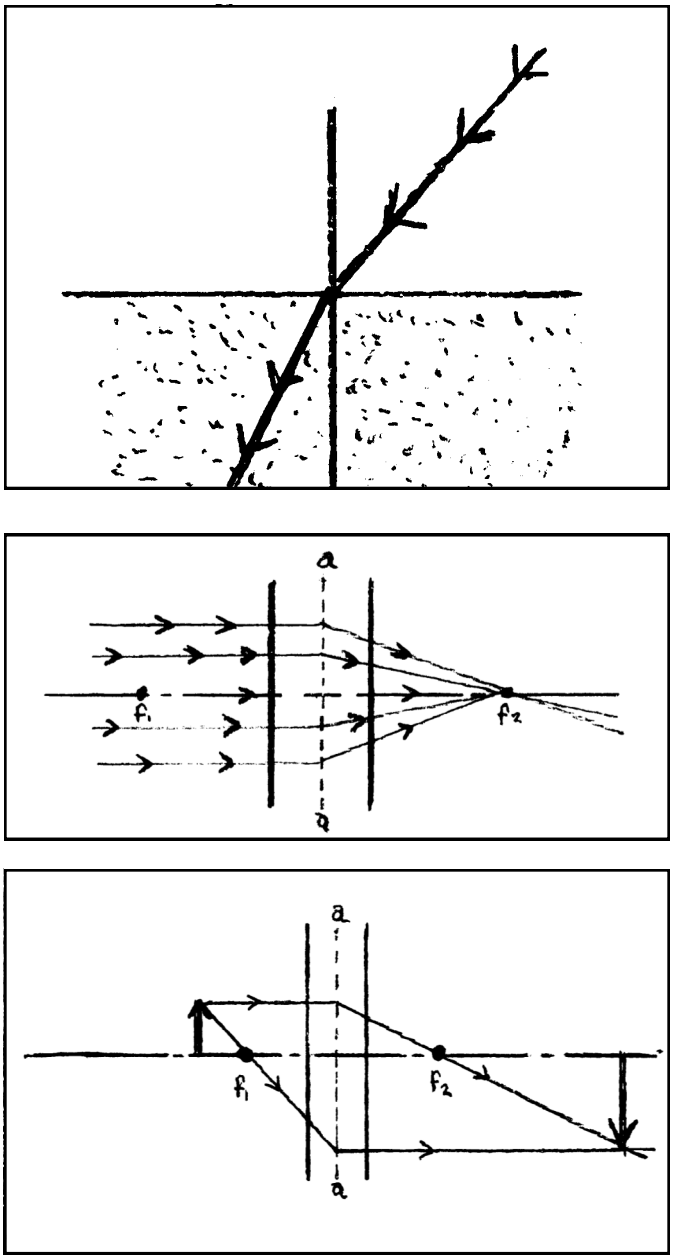

Fig. 1. Principles of optics. (A) A light ray entering from air into an optically denser medium, such as water or glass, is bent toward the normal. (B) Diagram of an ideal lens. All light rays parallel to the optical axis must pass through the focal point on the other side of the lens. For simplicity, the two focal lengths of the lens are assumed to be equal and the two principal planes coincide. (C) Basic ray tracing diagram of an ideal lens. See technical notes at the end of the article for a more detailed explanation of the diagrams.

the two liquids will have a refractive index higher than that of pure water, and Mr. Fields's stick will appear more crooked than in water alone (Temperance lecturers please take notice!). Refractive indexes are reported relative to air, with values for glass running from 1.5 to 1.8.

For six centuries, the subject of optics made little progress until the advent of the Arab opticians of the 9th to the 11th centuries A.D. Alhazen's work stands out above the rest. Alhazen re-investigated refraction from plane surfaces but, unlike Ptolemy, left no table of results. However, he went further than Ptolemy and investigated refraction from a single spherical surface. Although several of his propositions hint at a plano-convex lens, he fell short of realizing its value. Disney et al. argued that no optical instrument even of the simplest kind existed before 1000 A.D., and probably not before 1270 A.D.[9] The first of these probably were simple magnifiers, then eyeglasses. In the 13th century, some 200 years after Alhazen, a revival of learning occurred in Europe. By 1200 A.D., the great universities of Bologna and Salerno in Italy, Cambridge, and Oxford in England, and that of Paris in France all had been established and were attracting large numbers of students.

An important figure in the development of optics was Roger Bacon (1214-1294) (Fig. 2). Bacon belonged to a wealthy family and was enabled as a young man to buy books. In the 13th century, all books were hand-lettered copies, and as a result, were quite expensive. In addition to study, Bacon devoted himself to the pursuit of practical science. At the age of 30, he joined the Franciscan order and devoted himself to teaching and lecturing, as the order frowned upon experimental science. As a teacher he gained great respect and renown and worked both at Oxford and Paris, receiving a doctorate in philosophy from the latter institution in 1247. In 1266, the now famous lecturer and teacher was asked by Pope Clement for his views, and Bacon responded with three works that contained the knowledge of his day. In little more than one year after the request, Bacon wrote and sent to the Pope the *Opus Majus*, the *Opus Minus*, and the *Opus Tertium* . Optics made up about 1/5 of the *Opus Majus*, and also part of the *Opus Tertium*. Whether Clement ever received these works is uncertain, as he died in 1268 and the originals disappeared.

Fig. 2. Roger Bacon (1214-1294)

Bacon's discussion of refracted vision has been interpreted as evidence that he knew of the telescope, but this notion is now discredited. His discussion of magnification consists of noting that a plano-convex lens laid on the letters of a book will magnify them, and that such a lens is useful for those with weak eyes. This suggestion is a far cry from eye glasses, for which some have claimed him to be the inventor. There has been a tendency in the past to read more into Bacon's writings than they actually contain. For example Thomas Young (1773-1829), in his work of 1809 on *Natural Philosophy*, attributed the magic lantern to Bacon, along with eyeglasses, and suggested that he might have invented the telescope, citing the writings of Raconde (1551) and Diggs (1551) for this last claim.[10] However, there is no evidence that Bacon had a laboratory or did any experimental work on optics.

Nevertheless by the end of the 13th century, spectacles were definitely in existence, so others must have been experimenting with lenses during Bacon's lifetime. In 1305, a preacher of Pisa claimed that eye glasses were barely 20 years old, and an inscription in the church of Maria Maggiore in Florence states that the inventor of spectacles was buried there in 1317.[11] Once again, we must fast-forward about 200 years to the 16th century, and although spectacles were in use during the intervening years, no progress appears to have been made in optical science. Girolana Cardan (1501-1576), in his work titled *De Subtilitate*, described fitting "a glass disk " to a hole in a window shutter in a closed room to create a view of the outside on the opposite wall. If this glass disk was a convex lens, then Porta's claim for this invention, the camera obscura, is disputed.

Giovan Battista Della Porta (1543-1615) (Fig. 3) showed unmistakable intellectual ability, and at the age of 15 published the first four books of his *Magia Naturalis sive de Miraculis resum Naturalium*, which subsequently grew to 20 books by 1589. Porta described a camera obscura using a "lenticular crystal" or double convex lens in the 1597 edition of his work.[12] However Daniello Barbaro (1513-1570), a Venetian nobleman in his work, *La Pratica della Perspettiva* of 1569, had described the same system 30 years earlier. Although it apparently is a small step from the camera obscura to the magic lantern, it took some time for this transition to occur. In an age when relatively few people could read or write, when books were few and expensive, and when news traveled via a man on horseback or via a sailing ship, it is not surprising that progress was slow. Also, in the 16th and 17th century, there was the ever-present danger of being accused of witchcraft. Most historians feel that experimentation with combinations of eyeglass lenses must have occurred, and no doubt the magnification of near and far objects was investigated, but one must recognize the value of a discovery before any notice is taken.

It is thus not too hard to understand the slow pace in optical instrument development if the early experimenters saw no utility in magnification. With respect to the telescope, Thomas Diggs (1545-1595), in the first edition of his *Pantometria* in

Fig. 3. Giovan Battista Della Porta (1543-1615)

1571, described what appears to be a telescope constructed by his father. Similarly, William Bourne, in the time of Elizabeth I, described also what appears to be a telescope consisting of a concaved spherical mirror and a convex lens. The more accepted account of the invention of the telescope is by Dr. Moll of Utrecht and was published in the *Journal of the Royal Institution* in 1831. Moll reported that another researcher, Van Swindon, had found among the papers of Christiaan Huygens in the library at Leyden a petition dated 1608 by Jacob Adriaanzoon , also known as James Metius, addressed to the States General, for exclusive rights to sell his invention by which distant objects appeared larger and distinct. The same year also saw a petition submitted by Hans Lippershey (1570-1619) to the officials at the Hague for the same invention. Others attribute the telescope to Zacharias Jansen (1580-1638) as early as 1590. Similarly, Lippershey's claim has been dated by "reliable witnesses" to the dates of 1605, 1609, and 1610.[13]

In 1609, Galileo (1564-1642) heard of the Dutch invention and constructed telescopes of first 3x, 8x (18x?), and finally 30x magnification. In 1610 he made his famous astronomical observations which included mountains on the moon, and four of Jupiter's satellites. Galileo's real innovation however, was using the telescope to study the heavens. Galileo's astronomical observations created a demand for his telescopes, which he endeavored to supply. In a letter of March 19, 1610, he stated that he had made upwards of 100 telescopes, of which he had retained only 10. For lens manufacture, Galileo turned to mirror makers,

ornamental stone polishers, and, quite naturally, spectacle makers, who adapted their equipment to the manufacture of telescope lenses as best they could. Finding suitable glass of required clarity, free of striations and uniform in composition, was a major problem. Broken mirrors reground into lenses often were satisfactory. Glass quality was so variable that often the vast majority of the lenses produced were useless. In 1616, Giovanni Francesco Sagredo (1571-1620), a Venitian glass technologist and facilitator in Galileo's telescope manufacture, reported that one lens grinder had produced 300 lenses, of which only a small number was serviceable[14]. Incidentally if you bought a telescope from Galileo, you received a small package containing two lenses and a piece of string. The buyer was expected to use local talent to construct the telescope tube and the string was to tell the tube builder how far apart to position the lenses. Unless you were a Royal patron, shipping problems prevented the supplying of a complete instrument.

About 1618 or 1620, Galileo's two Venice glass supply agents were lost to him, Sagredo through death and the other through blindness. However, in 1618, Archduke Cosmo I established a glass works at the Medici Palace in Florence for the production of luxury glassware. It was in this establishment that Galileo found a talented young craftsman, Ippolito Francini (1593-1653), and under Galileo's direct supervision was making astronomical quality lenses by 1619. Francini continued to make lenses until about 1635-37, when Galileo, burdened with illness and blind, could no longer supervise the work. Francini produced lenses of far better quality than any made before and probably produced the first scientifically designed ones.[15]

Thus the improvement in the manufacture of optical instruments depends upon advances along three fronts: glass technology, optical design, and lens manufacturing techniques. Considering Galileo's problems in the infant telescope manufacturing business, it is easy to see why the magic lantern was not developed earlier. Optics technology, even if the design was know, was not up to the required level much before the first decades of the 17th century. With respect to the microscope, the same period of invention of 1590-1609 is generally accepted.[16] It should be noted that only microscopes dating from the last half of the 17th century exist in public and private collections, and no instrument prior to this period can be reliably dated.

The first published description of the magic lantern is in *Ars Magna Lucis et Umbrae* (*The Great Art of Light and Shadow*) (2nd edition, 1671) by the German polymath Athanasius Kircher (1601-1680) (Fig. 4). Both Clay and Court[17] and Disney[18] claimed that since the magic lantern was not specifically mentioned in the first edition of 1646, that it must have been invented after that date. Kircher's illustration and his description of the magic lantern in the text have generated considerable speculation, since the instrument as illustrated does not show a projection lens in front of the slide. Wagenaar suggested that Kircher's illustration is that of a point projection

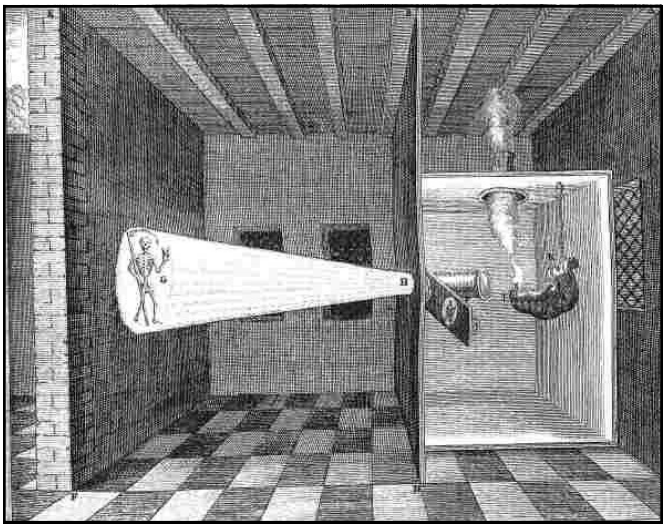

Fig. 4. One of the illustrations of a room-sized magic lantern in Kircher's *Ars Magna Lucis et Umbrae* (1671). Note the position of the lens between the lamp and the slide.

device.[19] Point projection devices require no lenses, do not reverse or invert the image, require small bright light sources, and give poor quality images. The image on the slide is not inverted, nor is the projected image in Kircher's illustration, lending support to this view. It is instructive to extend the cone of light shown in the illustration back into the lantern. The cone apex falls just about on the lamp flame as it would in a point projection device containing no lenses. The tube in this case merely keeps stray light off the slide. The illustration must be reconciled with the text which states that the slide must be either reversed or inverted depending upon translation of the Latin.[20] Similarly the presence of a lens in the tube is described. In short Kircher seems to describe a conventional magic lantern, but illustrates a point projection device. See technical note 7 for experiments on point projection that are easy to perform.

It should be noted that errors in illustration are common in pre 18th century literature, e.g., the giant man-sized microscopes illustrated in Rene Descarte's *Dioptrique* of 1637 and Gaspar Schott's *Magia Universalis* of 1677. These are shown in correct proportion in other 17th century texts and are discussed and illustrated in Bradbury.[21]

Dechales, in his *Mundus Mathematicus* of 1680, claimed a Dane showed him a magic lantern with two convex lenses in 1665. The Dane was Thomas Walgenstein and is referred to by Kircher.[22] Eder, in his *History of Photography*, claimed that although Walgenstein was not the inventor of the magic lantern, he made improvements to it and probably was the first true magic lantern showman.[23] There apparently were demonstrations at Paris as early as 1662, Lyons in 1665, and in Rome before 1670, and perhaps as early as 1660. Walgenstein's lantern had a concave mirror and a double lens projection system. He traveled extensively in Europe giving dem-

onstrations, but apparently rarely revealed the design of his lantern. Eder claimed that the true inventor of the magic lantern was Christiaan Huygens (1629-95), basing this claim on a description of the instrument found in correspondence with his brother dating from 1656. Walgenstein was a student at the University of Leyden in 1658 and knew Huygens, and thus no doubt learned of the latter's invention. Huygens distanced himself from the magic lantern, apparently being afraid that his reputation as an astronomer, mathematician, and natural philosopher might be tarnished if it became known that he was the creator of a device that was intended to produce ghostly apparitions. Huygens's father, ambassador from the Netherlands to the French court, desired a magic lantern, but his son avoided supplying him with one, no doubt due to the above mentioned concerns. More recently, Rossell placed the earliest date for Huygens' lantern at around 1659.[24] Huygens employed a projection lens composed of two separated double convex lenses, similar in construction to the compound negative eyepiece that bears his name and is still widely used today.

In its final form, the Huygens eyepiece consisted of two plano-convex lenses with focal lengths of 3 to 1 to 2 to 1 spaced at a distance equal to ½ of the sum of their focal lengths. The longer focal length lens faces the light and is called the field lens. The lens closest to the eye is called the eye lens, and the convex surfaces of both face the light. The field lens increases the field of view and was first applied to microscopes about 1660. With a ratio of two between the focal lengths of the eye and field lens, both coma and lateral spherical aberration can be corrected with lenses adjusted for an angular magnification of 21.3 degrees (see technical note 6).[25]

In 1664 Pierre Petit made a sketch of Walgenstein's lantern which clearly shows two lenses in the projection lens, no doubt a construction borrowed from Huygens.[26] That same year Petit wrote to Huygens for advice on the placement of the lenses in a magic lantern he was constructing. The lens closest to the light had a focal length of 7-8 inches, and that facing the screen about 12. Spacing the lenses at 8 inches would give a focal length for the combination of 8 inches and would closely follow the Huygens eyepiece design.

The first illustration of a magic lantern in English appeared in William Molyneux's *Dioptrica Nova* of 1692 and probably represents the design the opticians produced in quantity for the trade.[27] It featured a single convex lens as a projecting lens and represents a step backward in optical design over the potentially better image quality of the two-lens design (Fig. 5). Such lanterns were later produced and sold as children's toys into the early 20th century. Practical optical design is always a compromise, and before the development of non-reflecting optical coatings in the 20th century, increasing the number of lenses in a system could drastically reduce the light levels and contrast. Robert Hooke, in the preface to his *Micrographia* of 1665, stated that he removed the field lens from his microscope when critical viewing was required, sacrificing field of

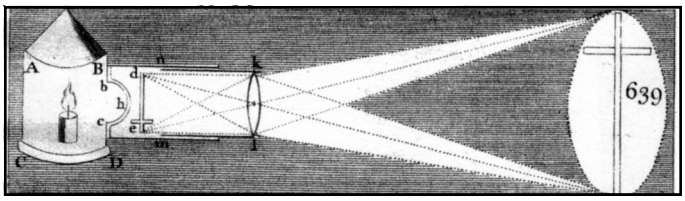

Fig. 5. Common magic lantern illustrated in Smith's *Opticks* of 1738, after Molyneaux (1692).

view for a better image. Thus with low intensity light sources, a single lens may have been a better choice for ordinary trade purposes

The lack of interest in the magic lantern in the 17th century by English "men of science" is reflected by the fact that only two references to it are to be found in the *Philosophical Transactions* of the Royal Society prior to 1700, and there are none in the 18th century. One of these is by Robert Hooke in 1668,[28] who described the principles of the camera obscura and the magic lantern in very general terms. Another article, titled "Magic Lanthorn Improved" by Sir Robert Southwell in 1693,[29] consists of a short paragraph and recommends "oil of Spike" mixed with a "variety of colors" as a good transparent paint to use for making lantern slides. He stated this advice as follows: "There are every made these Lanthorns to represent and magnify Figures upon a wall but this tis only in the Dark wherefore to give a variety of colors, take oil of spike and therein mix the several colors."

Early magic lanterns had a fixed illumination system, and for proper operation at various screen distances, both the lamp and the mirror should be movable along the optical axis. An adjustable mirror was first suggested by M. I. L. de Vallemont in 1693, and an adjustable lamp by J. M. Conradi in 1710. Both of these suggestions were included in a design by Willem Jakob Storm van s'Gravesande (1688-1742), which was published in the first edition of his *Mathematical Elements of Natural Philosophy Confirmed by Experiment* of 1720-21. Written in Latin, it was translated into English at the author's request by J. T. Desaguliers and appeared the same year as the Latin edition. The text was revised, and a second Latin edition was issued in 1725. The English 2nd edition corresponds to the Latin first (volume 1 only) and appeared in 1721. The English 3rd edition of 1726, the 4th of 1731, and the 5th of 1737 all correspond to the Latin 2nd edition. In 1742, the year of his death, Gravesande issued a major revision in the 3rd Latin edition with 127 re-engraved plates, as compared to the former editions, which contained only 58. However, the illustration of the improved magic lantern remained the same in all editions. It was again translated by Desagulieers and was published by his son in 1747.[30]

Before the section on optics went to press, Gravesande examined Smith's work on *Opticks* of 1738. He made no comment

on the illustration of his magic lantern, copied almost exactly from his earlier edition, but did comment that Smith's treatise is "an entire treatise of optics as his gives the elements only." Smith stated that the "Magick Lantern" or the "Lanterna Megalographica," as it was sometimes called, is an optical instrument "which optic writers have not altogether passed by, yet have not sufficiently improved."[31]

Fig. 5 is Smith's plate for the common form of the magic lantern, copied from Molyneaux. ABCD is a tin lantern and "bhc" is a "deep convex lens" (not illustrated properly in the plate), which serves as a condenser. Its purpose was to "strongly cast the light of the flame" on the slide. Sometimes the condenser was omitted, and an image of the lamp flame formed on or just before the slide by a concaved spherical mirror behind the light source (Fig. 6). Some 250 years later, 35mm theater motion picture projectors are still using this basic arrangement of a concave spherical or elliptical mirror without a condenser lens, traditionally using an arc light for the light source, but mostly replaced today with high pressure xenon arc lamps.

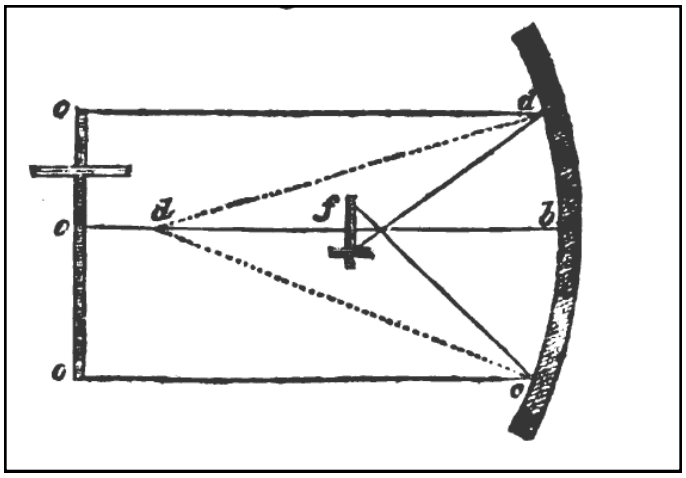

Fig. 6. Diagram showing the formation of an enlarged image with a spherical concave mirror. The cross at *f* is imaged at left. If a lamp flame is located at *f*, then its image will be at left and can illuminate a lantern slide directly or fill the back focal plane of a condenser lens. *From Library of Useful Knowledge, Natural Philosophy Vol. 2* (London, 1832).

Often, in Smith's time and much later, both condenser and spherical mirror were used together (Fig. 7). The slide at "de" in Fig 5 was described as "Usually some ludicrous or frightening representation the more to divert the spectators" and were painted on the glass in "thin transparent colors." The projection lens is at kl in fig 1. As to the construction of the lantern in Fig. 5, Smith stated: "This is so ordinary amongst the common glass grinders that it is needless to insist farther thereon in this place. It is sufficient to me that I have explained the theory thereof."

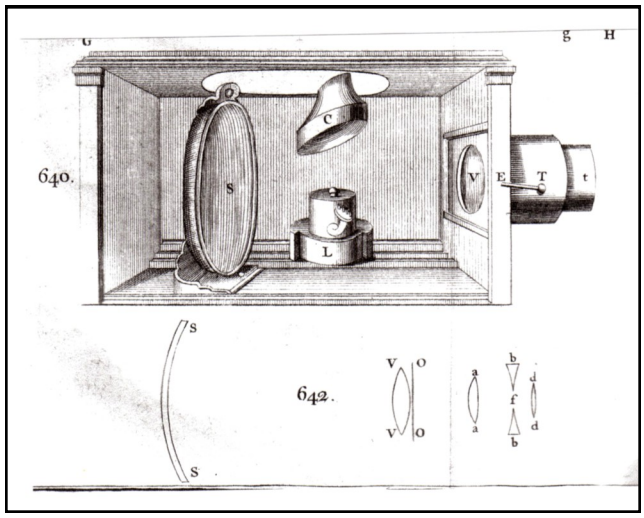

Fig. 7. Improved magic lantern by Gravesande. The illustration is from Smith's *Opticks* (1738) and is an nearly exact copy of Gravesande's original engraving.

Smith, however, did go on to describe the improved form of the lantern attributed to Gravesande (Fig. 7). The lantern proper consisted of a wooden box 18 inches long, 14 inches wide, and 14 inches high. The lantern was illuminated by a lamp which had four wicks whose flames converged to create one flame that was 2 inches wide. Behind the lamp was an 8 inch diameter concave spherical mirror with a radius of 18 inches (9" focal length). The center of the lamp flame was aligned with the axis of the mirror and also with that of a 5 inch diameter biconvex condenser lens with a radius of one foot. Using Smith's value for the refractive index of glass of 1.545 yields a condenser focal length of 11 inches (see technical note 1). The lantern lamp housing was equipped with a sliding chimney, which could be exactly positioned over the lamp as both the lamp and the mirror were capable of adjustment along the optical axis of the lantern. Fixed to the front of the lantern and concentric with the condenser lens was a tube 6 inches long and 6 inches in diameter and inside this tube (labeled "T" in Fig. 7) slid the projection lens housing, which was 4 inches in diameter and 6 inches long. The projection lens consisted of two elements with a diaphragm or stop between them. That nearest to the condenser was a double convex lens 3.5 inches in diameter with a one foot radius, thus having a focal length of 11 inches (see technical note 1). Separated from it by 3 inches was another double convex lens of 48 inch radius, which resulted in a focal length of 44 inches. The combination thus had a focal length of 9.4 inches (see technical note #2). The diaphragm or stop had a central opening of 1.25 inches in diameter and was positioned one inch behind the front lens of the combination, limiting the f# to 7.5.

Gravesande had all his instruments made by Jan van Musschenbroek (1692-1671), and it was he who introduced the central stop in the projection lens, borrowing the idea from a very early microscope attributed to Jansen. This stop served to control chromic and spherical aberrations to some extent, but also reduced screen brightness, and more will be said of these problems later. Smith noted that the positioning of this stop was critical to lantern performance. Smith also pointed out that the lantern could be used at 15, 20, or 30 feet from a white wall. Given Smith's data on the lantern, it is possible to calculate the size of the image at each of these distances assuming, as Smith recommended, a circular slide of 5 inches in diameter. These calculations are shown in Table 1 and the calculation outlined in technical note 3). Smith cautioned that the lantern should be mounted on a stand of adjustable height so it may be centered with respect to the screen center.

Table 1. Characteristics of Gravesande's magic lantern, based on data in Smith's *Optics* (1738).

Screen distance (feet)	Image diameter (feet)	Relative screen brightness
15	8.25	1
20	11.14	.55
30	16.90	.24

It is important to note that Gravesande used 3-inch diameter lenses in his projection lens. It is the function of the condenser –mirror system to evenly and strongly illuminate the slide, and this is accomplished by focusing the image of the light source into the projection lens. With a 2-inch wide flame, the projection lens must be large to accept the full image of such a large light source. With a non-coherent light source, it is impossible to focus the light to a brightness greater than that of the source itself; hence the need in a magic lantern for a large diameter projection lens if large sources of light, such as flames, are used.

Note the "terrifying devil "being shown on the screen in Fig. 8. Such slides were apparently in common use. John Harris (1666-1719), in his 3rd edition of 1716 of the *Lexicon Technicum*, described the "Magick Lantern" as follows: "A little Optic Machine of which are represented on a wall in the dark. Many Phantasms and terrible apparitions which are taken for the effects of magick by those ignorant of the secret. Always the most formidable are chosen and such are most capable of terrifying the spectators."[32] Gravesande recommended round slides mounted in wooden strips, which could contain as many as three views. Alternatively, the pictures could be painted on long strips of glass. Note that the slide diameter is that of the condenser lens. This arrangement results in the most efficient use of the available light that is possible and the largest and brightest projected image. It should be remembered that all optical instruments that use circularly symmetrical optics, be it

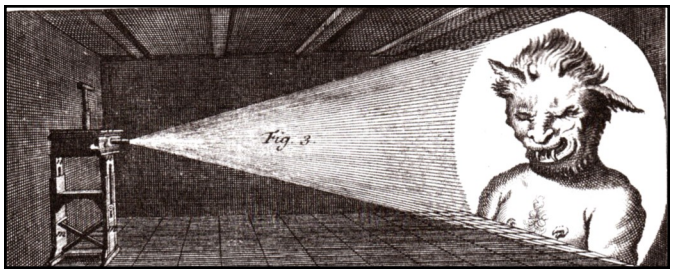

Fig. 8. Gravesande's magic lantern in use from his *Natural Philosophy*, 6th ed. (1747). Note the image of the "terrifying devil" being exhibited.

a microscope, telescope, or a magic lantern, produce a circular image or field of view. Any departure from this arrangement means the introduction of a mask in the optical system, which will limit image size at a given screen distance and the available light.

Gravesande stated that "to make the machine perfect": (1) The slide should be enlightened as much as possible; (2) The light should be even; (3) All parts enlightened (on the slide) should pass into the projection lens. (Basically this means that the image of the light source should be focused on the rear aperture of the projection lens by the condenser system); (4) The lantern housing should be light tight to keep extraneous light off the screen.

In using the lantern, Gravesande stated that the concave mirror, or speculum, and the lamp flame should be adjusted so that the image of the flame fills the rear aperture of the condenser. Not only was the lamp adjustable, but also the lamp chimney, so that it could be positioned exactly over the lamp flame. He went on to say in the last edition (3rd Latin, 6th English) that the sun is the best source of light for the lantern and pictured the apparatus (Fig. 9) that he employed. A window was covered with a board with a "suitable hole" for the lantern at "cc" in fig 9. The hole was covered with a sheet of oiled paper. When the sun shown on the oiled paper, the slide was "strongly illuminated." Gravesande went on to state that

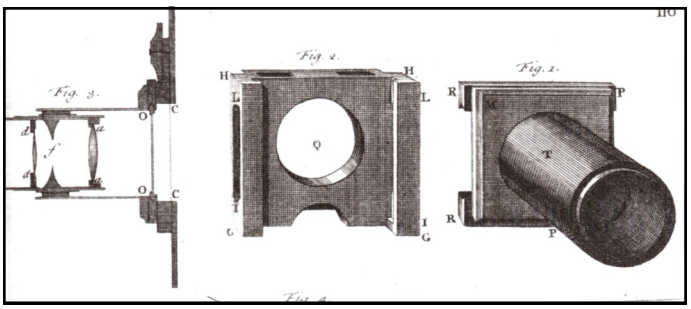

Fig. 9. Gravesande's solar magic lantern. From his *Natural Philosophy*, 6th ed. (1747). Note that the oiled paper at CC acts to diffuse the sun's rays entering from the right.

omitting the oiled paper greatly reduced the brilliance of the image and failed to mention that in the northern hemisphere, unless the window/lantern combination was on a south wall, the results would be disappointing in the extreme. The oiled paper illumination scheme is not a good one and is an offshoot of the camera obscura. The solar microscope or projection microscope of the period employed a superior illuminating arrangement consisting of a plane mirror equipped with suitable adjustments to direct the image of the sun into a condenser lens. Such a microscope could project the image of a louse to a size of six feet, but a size of three feet was considered superior in quality.[33]

Although Gravesande described a number of microscopes in his *Natural Philosophy* of 1747, he made no mention of the solar microscope, although one is described in Baker's work *The Microscope Made Easy* of 1742, and one is illustrated in the 2nd edition of 1743 and subsequent ones.[34] The plate was available at no cost to those who bought the first edition, lest they feel cheated. Baker attributed the invention of the solar microscope to Lieberkühn, but in the Dutch translation of his work in 1744, the translator added that it was actually invented by Fahrenheit sometime prior to his death in 1736. Clay and Court claimed that the plane movable mirror and fixed tube design were due to the English optician Cuff and that this was not a feature of the original instrument.[35] The original design was along the lines of a telescope mounted in the center of a light tight ball and socket arrangement. The instrument was pointed at the sun and the image was projected on a plane perpendicular to the optical axis of the instrument (Fig. 10).

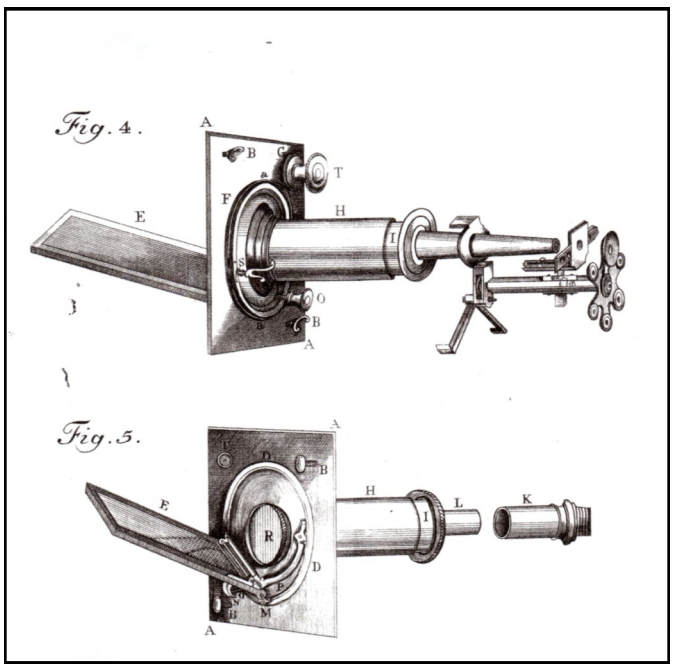

Fig. 10. Illustrations of solar microscopes, from George Adams, Sr., *Micrographia Illustrata* (1746).[36] The microscope was mounted in a hole in an otherwise covered window. The mirror at *E* directed the sun's rays into the condenser at *R*.

English descriptions of the magic lantern in later 18th and early 19th century technical works repeat essentially what has been stated so far about optical design. Thomas Rutheforth (1712-1771), in his *System of Natural Philosophy* of 1748, gave a diagram of a magic lantern nearly identical to that of Fig. 5 and noted that the projection lens must be very convex.[37] He also mentioned the use of a candle as an illuminant, a weak light source indeed! This author, however, did discuss the solar microscope in its improved form, as shown in Fig. 10. William Emerson (1701-1782), in his *Elements of Optics* of 1768, described a magic lantern, but gave nothing new.[38] Emerson's lantern was either a "tin lanthorn" a foot in diameter or a "square wooden box." Once again, the slides represent "ludicrous or frightful figures," and he added that "small living animals" may be exhibited "and some of which make a most terrible appearance." Emerson's slides were small, as they fitted in a slot in the side of the projection lens support tube, which was 4 inches in diameter. The projection lens was either of 3 inch or 6-8 inch focal length, of which the 6-8 inch is the more reasonable.

Next to Smith's *Optics* of 1738, Joseph Priestley's *The History and Present State of Discoveries Relating to Vision, Light, and Colours*, published 1772, was the most important English work on optics of the 18th century.[39] Newton's *Optics*, first published in 1704, with a second edition in 1718, I feel really belongs to the 17th century. Priestley (1733-1804) gave Kircher the credit for inventing the magic lantern, but commented on his illustration of it in his *Ars Magna…* of 1671: " Kircher with all his ingenuity of which it is impossible not to Conceive a very great opinion, had not the art of making his lamp Burn without smoke; though it is possible that the designer he Employed might, in order to show his skill in drawing make a greater cloud of smoke, both from the lamp and chimney belonging to this Instrument than in fact ever issued from them." Errors in illustration were very common as mentioned previously. Perhaps, however the smoke was intentional. What would be a better to accompany views of devils and apparitions than smoke issuing from the mysterious lantern that was creating them?

Priestley, however, added that the magic lantern, "is capable of making so much diversion to children and persons unacquainted with the principles of optics and even to philosophers Themselves in an hour of relaxation that it certainly deserves to be described in this place." His illustration of the magic lantern is nearly identical to Fig. 5, and his discussion of it adds nothing new. With respect to the solar microscope, Priestley gave credit for its invention to Lieberkühn and mentioned that he showed his invention in the winter of 1739 during a visit to England to several gentlemen of the Royal Society, as well as some opticians, particularly Mr. Cuff in Fleet Street.

George Adams, Jr., in his *Lectures on Natural Philosophy* of 1794 stated " The magic lanthorn has been generally applied to magnify small pictures in a dark room for the amusement of children: we shall shew you that it may be applied to more important purposes by using it to explain the general principles of optics, astronomy, botany and etc."[40]. He illustrated a lantern no different than those of any of his predecessors, and there is no evidence in his *Lectures* that he followed up on his suggestion quoted above. George Adams Sr. (1710- 1773) and both of his sons, George Jr. (1750-1795) and Dudley (1760-1826), were prominent London instrument makers. George Jr., unlike his father, listed magic lanterns in his catalogue, a copy of which was bound with his *Essays on the Microscope*, published in 1787. Adams listed a magic Lantern at 1£ 5s, or about $6.25 in US currency, assuming 1£ = $5.00, a hefty sum, but not nearly as pricy as some of his other instruments. For example he listed a telescope to be used at sea at night for 1£ 11s 6d (1 pound 11 shillings and 20 pennies, with 20 shillings to the pound, and 12 pennies to the shilling). A 3-foot reflecting astronomical telescope with 4 eyepieces for different magnifications and rack work focusing could be had for 36£ 15s. Microscopes ran from about 2 to 21£, and solar microscopes were listed at 5£ 5s and 16£ 16s, the latter capable of imaging opaque objects by reflected light. Spectacles ran from 1£ 16s for the best with double jointed silver frames and lenses made from Brazil pebbles (clear quartz), to as low as 1s for a pair done up in horn and steel with glass lenses of perhaps doubtful quality.

As long as optical instruments used combinations of simple lenses made of identical types of glass, they could not be improved past a certain point due to lens aberrations. To understand the problems we must now consider a few basics of optics. For diagrammatic purposes an "ideal lens" is represented by two parallel lines along the optical axis as shown in Fig 1b. The lens is characterized by two principal planes where, for diagrammatic purposes, the change in direction of the light rays takes place, depending upon the direction that the light enters the lens. For our purposes we will assume that they coincide and hence only one is shown, "aa". Our ideal lens also is characterized by focal points f_1 and f_2 on either side of the lens and we will assume that they are both equal in distance from the principal plane. Our ideal lens could be for any type of radiant energy, although we are concerned only with visible light. Note that what goes on inside the lens or any details of its construction are of no concern. Our ideal lens so described has the following properties:

(1) Each ray or pencil of light proceeding from a single image point, i.e., in the case of the lantern, a given point on the slide after passing through the projection lens converges to a single point on the image. The ray or pencil of light also can diverge from a single point of the image, but this is of no concern with the lantern since we are concerned only with real images and not virtual ones.

(2) If the object, i.e., the slide, is perpendicular to the optical axis of the lens, the image of any point also must be in a plane perpendicular to the axis of the lantern**.** This part of the definition rules out the past claims of projecting images on clouds of smoke, since there is no image plane in a smoke cloud. Probably a thin gauze was used for a screen along with rear projection, with smoke in front to create this illusion.. It must also be remembered that the distances must be scaled to the situation. A cloud bank, say 3000 feet from the ground, will reflect and scatter light back to the earth from a search light. At that distance a cloud bank serves as a more or less flat screen. This does not hold in a room 50 feet long and a smoke cloud at one end.

(3) The image must be similar to the object whether its linear dimensions are altered or not. If we take our ideal lens outdoors and use it to image the parallel rays of the sun we will discover that they will converge to a focus as shown in Fig. 1b.

Knowing the above we can by means of a scale drawing understand the behavior of a lantern projection lens when we project a slide on a screen. Situate a slide at some distance beyond the focal point of the projection lens, and, as Gravesande told us, illuminate it evenly and well and:

(1) Draw a line from any point on the slide, say a high mountain top, parallel to the optical axis and when it reaches the principal plane it must now change direction and pass through the focal point f_2 on the image side of the lens.

(2) Draw a line from the same high mountain top through f_1, and when that line passes through the principal plane it too must change direction and emerge parallel to the optical axis.

(3) The intersection of the lines created by steps 1 and 2 define where the image will be and its size; see Fig. 1C.

The above may be accomplished very easily by a simple formula given in technical note 3, but it is important to remember that the formula merely is a statement of the geometric principles outlined above. So much for ideal lenses. In the real world, glass lenses suffer from faults or aberrations, two of the most serious being spherical and chromic aberration, with chromic aberration being judged the most serious. Spherical aberration arises from the fact that lenses ground as segments of spheres do not bring the light rays from the edge of the lens to the same focus as those in the center, as shown in Fig. 11a. The problem can be solved by creating lenses with non spherical surfaces, but this was generally beyond any but late 20th century technology. The usual solution to this problem in the 18th and earlier centuries was to use only the central rays; hence the stop in Gravesand's "improved" lantern projection lens.

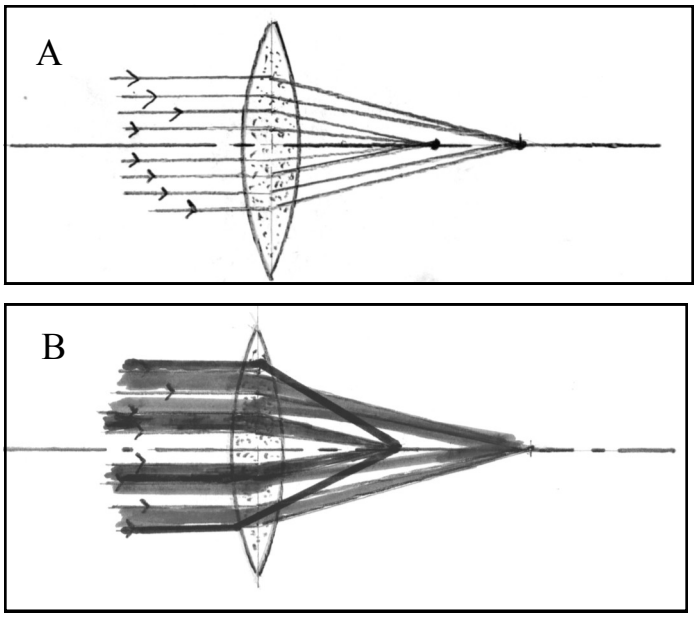

Fig. 11. (A) Spherical aberration. Light rays from the edge of the lens do not come to the same focal point as those near the center. (B) Chromic aberration. Light rays of different colors come to different focal points.

Chromic aberration, illustrated in Fig. 11b, is caused by simple lenses not bringing all wavelengths of light (colors) to the same focus, because the lens acts to some extent as a prism. Sir Isaac Newton (1643-1727), who first investigated the well-known phenomenon of a glass prism creating the colors of the rainbow from white light, thought that the chromic aberration problem was insolvable. Publishing his results in *The Philosophical Transactions* of the Royal Society in 1672, he demonstrated that each color of light was bent to a different degree by a prism; i.e., it had a different refractive index. By recombining the colors with a lens, white light was again created. Newton believed that it was impossible to achieve the bending of light by refraction without dispersion, i.e., without creating a rainbow, and hence chromic aberration could not be corrected. When a high authority in science claims something is impossible it is generally believed to be so and progress stops as it did up until about 1730 with respect to the chromic aberration problem.

In about 1733, a British barrister named Chester More Hall (1703-1771), who was also a skilled astronomer and optician, designed the first combination of lenses, which, at least in theory, should have corrected the problem of chromic aberration. Hall's lens combination consisted of a double convex lens of "crown" glass along with a concave one of a dense, high lead content glass known as "flint." He did not patent his invention, but did have an example of the combination manufactured, one component going to the commercial optician Edward Scarlett (1677-1743), the other to James Mann. Alas, this attempt at secrecy came to naught, as both subcontracted the job to an optician named George Bass. However, there the matter rested. Bass at least initially did not realize the significance of Hall's combination and Hall did very little further. There is a good chance that Hall's combination did not work, although he was definitely on the right track. The cementing together of the two component glasses with Canada balsam did not take place until the work of Abbé Rochon (1741-1817) in 1793. Air-spaced achromatic combinations are tricky to align and space and must be made to very high tolerances.

In the 1750s, the optician John Dollond (1706-1761) took up the problem. From Leonhard Euler (1707-1783), one of the foremost mathematicians of the 18th century, he learned that Newton might not have been correct about the chromic aberration problem. Later Samuel Klingstierna (1698-1765), also a mathematician, reinforced these views. From Bass, he learned of Hall's combination and realized its significance, and by 1758 he had designed and patented a successful achromatic combination of lenses which corrected chromic aberration, and he demonstrated the use of these lenses for projecting images. This accomplishment was the result of a great deal of well-executed experimental work, in addition to his learning of Hall's previous experiments from Bass. Dollond's achromats made superior telescope objectives, and other opticians had to pay him a much resented patent royalty to use his discovery for many years. (see technical note 5). In 1774, the optician Benjamin Martin (1705-1782) marketed a solar microscope for opaque objects equipped with a triple achromatic combination, but the expense of these complex lenses slowed their adoption for use in the magic lantern.

Although an achromatic microscope objective was produced as early as 1791 by Beeldsnyder, real improvement did not occur until the decade of 1820-1830, through the work of Tulley and Goring in England and Chevalier in France. In 1830, Joseph Jackson Lister (1786-1869) published a paper in the the *Philosophical Transactions* which provided a theoretical background for a design that largely corrected the spherical aberration present in earlier objectives.[41] Although slowly accepted at first, Lister's work eventually resulted in steady improvement of the ability of the microscope to see finer detail up to the limit of resolution determined by the wavelength of light and a lens parameter known as the numerical aperture of the lens, (see the tech note 4). The basic design that Lister used in his microscope objectives was later re-worked to create projection lenses, and that Lister's design is the basis for projection lenses in use today.

By the end of the 18th century optical design was beginning to progress to an exact science, and problems with lens aberrations were being seriously addressed. In addition to spherical and chromic aberration, opticians were recognizing that such problems as coma and astigmatism needed to be corrected. These defects are associated with oblique rays

and the outer portions of the lens away from the optical axis. In the case of coma (comatic aberration), images, such as those of stars viewed through a telescope, have a flared tail. Astigmatism produces different focal points for horizontal and vertical lines (see technical note 6).[42] Optical glass quality was a constant problem, and in the 18th and early 19th century glass makers were lucky to produce a disk much over 4 inches in diameter of suitable quality to be made into a telescope objective.

In 1764, M. Zicher of St. Petersburg, Russia, reported to the mathematician Euler that he could increase the dispersive power, i.e. the length of the solar spectrum as displayed by a prism, by adding larger amounts of lead oxide to flint glass than that normally used in its manufacture. For the first time, a single ingredient used in glass manufacture could be identified that influenced an important optical property.

As is often the case in technology and science, real advances often come from individuals outside the field of endeavor, and in the case of optical glass it was a Swiss clock-case and cabinet maker, Pierre Louis Guinand (1748-1824).[43] Interested in building his own achromatic telescope, he could not obtain suitable specimens of flint glass, and in 1783, at the age of 35, he began to experiment with glass manufacture, despite his lack of training in science and being totally dependent upon his trade for a living. Between 1784 and 1790, Guinand experimented with glass manufacture first starting in small 3-4 pound batches and eventually building a furnace that would melt 200 pounds of ingredients. Usually only a very small portion of a melt would be free from defects, and if one wanted large blanks for lens manufacture, a large melt was required. In 1805, Guinand's work attracted the attention of a wealthy Munich lawyer, Joseph von Utzschneider (1743-1840), who was then financing a company to produce high quality surveying instruments chiefly for the military. Realizing that high quality optical glass was essential, he began to finance Guinand's efforts and persuaded him to relocate to Germany.

Also in 1805, Guinand made a critical discovery: by stirring the glass melt with a fireclay stirrer, air bubbles were brought to the surface and even incorporation of ingredients was promoted. Stirring with a fireclay stirrer is still an important step in optical glass manufacture today. In 1807, his employer required that Guinand take on an assistant, Joseph von Franhoffer (1787-1826), a young man of 20 who was destined to become one of the greatest figures in the history of optics. The two did not get on especially well, and in 1814, Guinand left Utzschneider's employ and returned to his native Brenets, Switzerland with his former employer's blessing and entitled to a pension if he refrained from glass manufacture. This he did not do, and as a result he lost his pension. He spent the rest of his life in the construction of achromatic telescopes and supplied optical glass blanks, some as large as 10 inches, to such customers as the eminent French opticians Lerebour and Cauchoix. Meanwhile, von Franhoffer began a systematic investigation of refractive index as a function of color (wavelength) for a variety of different glasses, and these data enabled him to build some of the finest telescope objectives of the early 19th century. His 9.4 inch Dorpat refractor was for many years the finest refractor in the world.

During the early years of the 19th century, the magic lantern began to rise in status among optical instruments. As early as 1685, Johannes Zahn (1641-1707) had proposed the use of the magic lantern to illustrate anatomical lectures, and in 1705, Johann Conrad Creiling (1673-1752) at Tübingen recommended it for all educational purposes.[44] In the 18th century, magic lantern shows often consisted of ludicrous or frightening images, with children being singled out as a primary audience. The early lack of use of the lantern for educational purposes may very well be due to both low light source brightness and possibly to poor projector lens quality. Neither of these is very important if you are "raising spirits" to scare the ignorant, and by the last quarter of the 18th century, this class of show had become popular. Johann Georg Schröpfer (1730-1774) in Leipzig was noted for this type of presentation. The phantasmagoria show, where images of ghosts, etc. were rear-projected on a suitable screen, was brought to perfection by Robertson in 1798 and literally had people fainting in the aisles.

The phantasmagoria was introduced into England by Paul de Philipsthal in 1802 and thereafter began to lose its macabre character and gradually became an instrument of more gentle entertainment and education. A pioneer in this development was Philip Carpenter (1776-1833), a Birmingham optician who was one of Britain's leading figures in the 19th century optical trade as early as 1812. By this time, he was supplying most of the achromatic lenses used by British opticians. In 1821, he began to market phantasmagoria lanterns and had developed a process of copperplate printing and subsequent fusion which enabled the mass production of lantern slides.[45] The slides were available on a variety of serious scientific subjects, as well as on those of a more entertaining nature. An advertisement dating from about 1835 lists slides on natural history, views of the Holy Land, scriptural subjects, portraits of famous persons, and also lever slides, chromatropes, and dissolving views. By 1835, the limelight was in use, and slides could be projected to large audiences. Further improvement in the magic lantern did not really occur until after the application of photography to lantern slide production. Photographic slides were first made by the Langenheim brothers in 1849 and exhibited in Philadelphia in 1850-51 (22). The discovery of the colloidian process by Frederick Scott Archer (1813–1857) in 1851 gave real image improvement, and by 1860 or so photographic lantern slides were being marketed on a large commercial scale by Carpenter and Westley in Britain.[46]

Henry Coddington (1798-1845), in his work on optics of 1829[47], gave perhaps the first improved design of a projection lens since Gravesande. He was concerned in his

design with flatness of field. He achieved this goal by positioning a stop in front of the lens towards the screen. He also discussed a problem with the phantasmagoria lantern–the image grows brighter as the lantern is made to approach the screen, and that "some contrivance must be employed to stifle the light."

Further improvements in magic lantern lens technology came through improvements first made to photographic camera lenses. The French photography pioneer Joseph Nicéphore Niépce (1765-1833) used a meniscus lens, as suggested by the British scientist William Hyde Wollaston (1766-1828), for the camera obscura in 1812, and it was also adopted by Louis Daguerre (1787-1851), but it proved to be very slow. It was satisfactory for landscape photography, but exposures of about ½ hour and bright sun light were required. As early as 1839, Daguerre joined with Alphonse Giroux, a Paris optician, for the manufacture of cameras, and these were equipped with a cemented achromat provided by Charles Louis Chevalier (1804-1859), a foremost Paris optician and pioneer in developing the achromatic microscope (Fig. 12b). The Chevalier achromat gave about a 2x improvement in definition over the meniscus lens, but it too required bright sun and ½ hour exposure times. It is worth noting that meniscus lenses, in the days before anti-reflection coatings, often gave better results with landscapes than more highly corrected ones due to being thin and having only two reflecting surfaces. Meniscus lenses were used throughout much of the 20th century in cheap fixed-focus box cameras. Such lenses give reasonable definition at f#16 and a field of view covering no more than 50 degrees.[48]

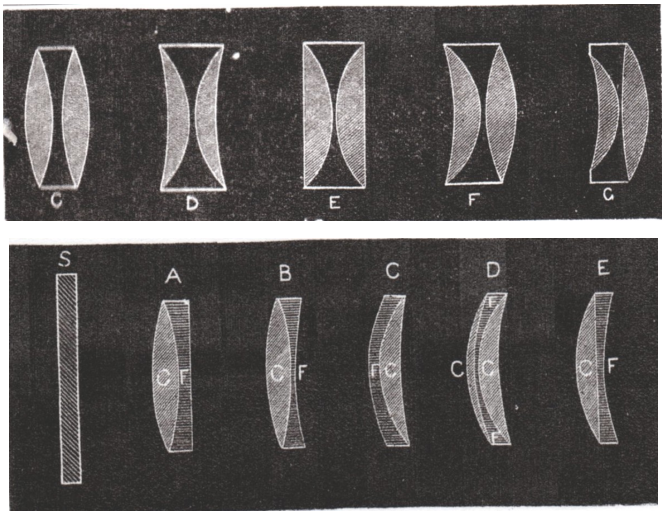

Fig. 12. (A) Condenser lens configurations. (B) Examples of cemented projection lenses. From Lewis Wright, *Optical Projection* (1890).

In 1839 the British scientist Sir John Herschel (1792-1871) coined the word "photography" in a lecture to the Royal Society. The new art created by science was on its way. It was quickly recognized that faster lenses were required if photography was to be used for portraiture, and in 1840 the Hungarian mathematician Joseph Petzval (1807-1891) designed the lens bearing his name. This lens, instead of being designed by trial and error, was computed using the refractive index data obtained by Joseph von Fraunhofer (1787-1826). Having an aperture of f# 3.6 - 3.4, it consisted of two achromatic elements. The front most one was an air spaced doublet consisting of a biconvex crown lens and a rear negative one of flint. The element nearest the camera was a cemented achromat (Fig. 13). The development of this lens, along with an increase in sensitivity of the Daguerre plate through exposure to bromine vapor, made exposures as short as 8 seconds feasible. This was a far cry from the first recorded portrait created in 1839 by John W. Draper (1811-1882), a New York photographer, whose photograph of the flour-powdered face of an assistant took a half hour to expose. Although the Petzval lens, as improved by John Henry Dallmeyer (1830-1883), had a speed of f#2.4, the basic Petzval design suffered from astigmatic defects in the outer part of the field, which could not be removed as long as ordinary crown and flint glass were used in its construction. Although not suitable for landscape photography, it was well suited to portrait work and became very popular. Manufacture of the lens was entrusted to the Voigtländer Optical Company, and by the 1850s, some 8000 had been produced.[49]

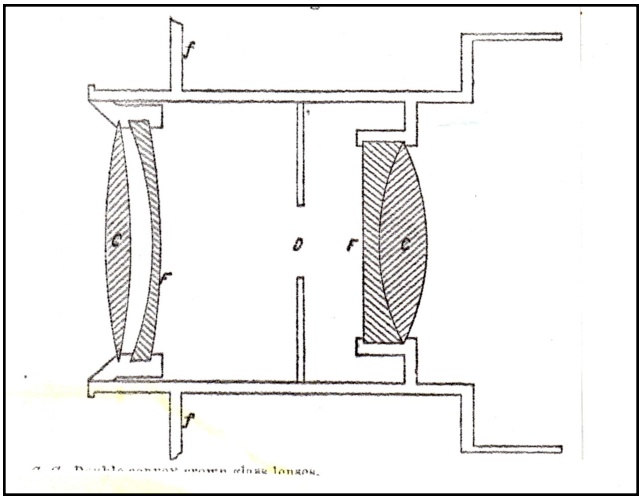

Fig. 13. Petzval portrait lens, 1840. The frong acromatic element (left) consists of a biconvex crown glass lens (*C*) and a rear negative lens (*F*) of flint glass. The rear achromatic element (right) consists of a cemented achromat lens (*F, C*). Although designed for portrait photography, it was a superior magic lantern projection lens. Often the entire lens was reversed in position when used in a lantern. From Cary Lea's *Manual of Photography* (1868).[50]

It was quickly discovered that such a portrait lens made an excellent projection lens for the magic lantern, with some qualifications. The basic Petzval portrait lens design, along with that of the previously mentioned 1830's designs of

of Lister for microscope objectives, became the prototypes of projection lens even down to the present day. In 1868, Lorenzo J. Marcy of Philadelphia patented his "Sciopticon Lantern." In his *Sciopticon Manual* of 1877 (6th ed), he described both the portrait objective and the "plain lantern objective." The latter was based on the Petzval design and consisted of a front "meniscus (lens) of crown glass" whose mounting tube slid into a larger tube which held a second achromatic lens. Reversing the sliding tube so as to bring both lenses closer together gave a larger, but less distinct image at any given distance. Using only a single lens gave a smaller image. Fig. 13 and 15 in the *Sciopticon Manual* show a reversed portrait combination.[51] T. C. Hepworth discussed projection lenses available in the latter part of the 19th century as follows: "Some use a couple of plano-convex achromatic lenses in conjunction with a stop or diaphragm, the flat side of the lens being next to the light." He went on to say: "I hold the opinion that a good single achromatic lens of long focus is by no means to be despised for lantern work although a half plate lens of the portrait type is to be preferred."[52] The term "half plate" refers to glass plate camera negative size of 6.5 by 4.75 inches.

Lewis Wright, at the end of the 19th century, illustrated and discussed in detail various single achromatic combinations that had been used, and they are illustrated in fig 12b. Wright claimed the simple achromat (Fig, l2b, A) worked best with the convex surface facing the slide (S in fig 12b). If reversed, definition was sharper in the center, but fell off rapidly towards the edges. This style of lens could not be made with a focal length of less than 4.5 to 7 inches and give satisfactory results. Configurations B, C, and E in Fig. 12b gave a flatter field but tended to introduce distortion. In focal lengths of 10 inches or more, spherical aberration was much less, and Wright thought they worked well.[53]

The approach of Lister, using the combination of two or even three long focal length achromatic elements, resulted in a much better short-focal-length lens than the use of a single achromat of short focus. It was thus a common practice to supply a lantern with 3 achromats of long focal length ranging from 9-10 inches up to 18-20 inches or so. These could be screwed together to give a range of focal lengths. Wright mentioned that some of these sets were good, others middling, and some bad. The wise buyer would subject them to a trial before making a purchase. Wright also mentioned triple combination lenses, consisting of two crown double-convex elements cemented one to each side of a double concave flint lens. These performed very well in Wright's opinion, even with focal lengths as short as 6 inches. He cautioned that his 6-inch lens, with a clear diameter of 1.75 inches, required a stop of one inch aperture positioned 2.5 inches in front of the lens for best results. With focal lengths above 9 inches, no stop was required. Recall that Martin used a similar, but air-spaced triplet in his solar microscope of 1774! (see technical note 6).

With respect to condenser lenses, Wright discussed a number of configurations, and these are illustrated in Fig. 12a. A single condenser lens sufficed until Carpenter and Westley adopted the double convex configuration shown in Fig. 12a (C) for their early phantasmagoria lanterns. This style was used for many years by these makers and was also employed by Dubosque. The use of a double condenser allows much thinner glass to be employed in each lens than would be used in a single lens of equal focal length, thus reducing absorption losses. Chromatic aberration is also somewhat reduced. The double convex configuration was abandoned because of imperfect chromic aberration correction and excessive loss of light at the edges due to reflection. Two meniscus lenses (Fig12a [D]) were an improvement, but never came into general use and were superseded by a meniscus and a double convex configuration with the meniscus element positioned next to the light source (Fig. 12a [F]). Although this configuration, due to Sir John Herschel, was admirably suited to producing a parallel beam of light from a point source, it was not so successful in converging light into the back element of a projection lens as required in lantern work. It worked well with the limelight, but not with larger light sources such as oil lamp flames.

The double plano-convex configuration shown in Fig.12a (E) is probably familiar to most of the readers and was adopted by Marcy for his sciopticon. If properly modified, it worked very well with limelight or electric carbon arc lamps and thus became the most common condenser arrangement and was recommended for all thermally hot light sources. The configuration shown in Fig. 12a (G) was attributed to Gravett and was well-suited to point sources such as the limelight or the electric carbon arc. Wright cautioned that unless one is projecting images to a size of 20-30 feet in diameter, condensers of ordinary crown glass were satisfactory. In the projection of large images the greenish tinge of crown glass became objectionable, so more expensive condensers of flint glass were recommended. Such flint glass condensers had diminished chromatic aberration at the edges where it is most serious, were colorless, and thinner due to the higher refractive index of flint glass. Thus by the beginning of the 20th century optical technology had progressed to the point that high quality images could be brought to the screen, the magic lantern showing the way in optical design for the newly invented motion picture projector.

With the advent of the movies the lantern passed into the hands of educators. I can recall that in the late 1960s and early 1970s, speakers at technical meetings still projected 3 ¼ x 4 inch lantern slides during their presentations. Polaroid even marketed an "instant" lantern slide film in the mid 1960s early 1970s. In 1937, Kodak introduced the 35mm slide format, along with the KODASLIDE projector, and the 35mm format began to gradually replace the larger Victorian era lantern slide. Numerous 35mm slide projectors

by Kodak and many other manufacturers followed. In 1962 Kodak introduced the CAROUSEL projector, and in 1967 the more professional version of the Carousel, the EKTAGRAPHIC. The Ektagraphic projector had an efficient illumination system and could deliver 1300 lumens to the screen; the Carousel 1000. A full complement of lenses was available, interchangeable between both models. Focal lengths of 2.5, 3, 4, and 5 inches, with speeds of f# 2.8 to 3.5, depending on focal length and a 4-6 inch zoom were available from Kodak. Longer focal lengths were available from other manufacturers. Also, lenses for projection on curved screens were available—a 102mm f#2.8, a 127mm f#2.8, and a 102-152mm f#3.5 zoom being offered. The curved screen was supposed to bring the audience closer to the presentation. The projection lenses, anti-reflection coated, computer designed and employing modern optical glass, gave excellent images on both curved and flat screens. Kodak stopped producing both the Ektagraphic and Carousel projectors in 2004, although they still are readily available on the internet. With the demise of the Carousel projectors I think we can safely say that the era of the magic lantern has officially ended; replaced by high definition television and digital photography. Will it ever rise up again and in what form? Who knows?

Technical Notes

(1) The focal length (f) of a thin simple lens can be calculated by the use of the lens maker's equation:

Eq1: $1/f = (u-1)(1/R_1 + 1/R_2)$

where R_1 and R_2 are the radii of curvature of the front and rear surfaces of the lens and (u) is the refractive index of the glass and (1) is the refractive index of air. The expression (u-1) is thus a measure of the refractivity or light bending ability of the lens.

(2) The focal length (F) of a two thin positive lenses combination separated by a distance (s) given by the expression:

Eq2: $1/F = 1/f_1 + 1/f_2 - s/f_1f_2$

It is often convenient to express the focal length of a lens in terms of its power ***in dioptres.*** This is merely the reciprocal of the focal length of the lens in meters. (39.37 inches/meter).

Our equation thus reduces to:

Eq2a: $D = d_1 + d_2 - sd_1d_2$

Where the "d "values are the respective dioptres values for the lenses in eq 2.

(3) **For a simple thin lens:**

eq3: $1/f = 1/p + 1/q$

Where (f) is the focal length and (p) the distance of the object from the lens and (q) the image distance. This equation holds for real images such as are involved in the magic lantern so long as both (p) and (q) are greater than (f). If the object is inside the focal distance a virtual image is produced and this case is of no concern with respect to the magic lantern. Knowing the distance from the screen and using eq2 one can calculate the distance of the slide from the lens. The image size is give by the proportion (eq. 4).

eq 4: $\frac{\text{Image length}}{\text{Object length}} = \frac{\text{image distance}}{\text{object distance}}$

(4) The Numerical aperture (NA) of a microscope objective is a measure of its light gathering power and is important because it, along with the wavelength of light employed determine the resolving power or the ability to see fine detail. The (NA) of an objective is related to the (f#) used in photography by the expression:

eq 5: $f\# = (1/2NA)$

This relationship holds in the case of the high magnifications used with the compound microscope. It often comes as a surprise to the photographers that the lower f# the better, according to theory, the resolving power. The theoretical resolving power is approximately equal to:

eq 6: $R = 1600/f\#$ line pairs per mm

Photographic lenses rarely approach this figure except above f# 8 or 11.

(5) An *achromatic lens* is corrected for two wavelengths of light or colors i.e. it brings two colors or wavelengths to the same focus which are almost universally red and green. An achromat could be corrected say to bring orange and blue light to the same focus but this is virtually never done. Achromats corrected for red and green are corrected for spherical aberration for one color, green. The chromic aberration is corrected by the use of a combination of two lenses made of different types of glass with for equal dispersion having unequal refraction. Thus by combining a positive lens such as a double convex converging lens of crown glass with a double concaved (dispersive) one of flint chromic aberrations compensate for each other. A ***converging lens*** is always thicker in the center than at the edges, a ***diverging lens just*** the opposite. Spherical aberration is eliminated by proper forms of the lenses.

Up until the work of Abbe and Schott in the last decade or so of the 19th century all types of optical glass known had

the property that as the refraction (mean refractive index) increased the dispersion or length of the color spectrum produced by a prism also increased but not necessarily to the same degree. Considerations for the correction for spherical aberration also dictate that the dispersion of the crown glass element must be less than that of the flint. The mean refractive index is measured using the sodium "d" spectral line of 589.3 nanometers (nm) wavelength. The dispersion is characterized by the difference in refractive index as measured at 486.1nm (F spectral line) and 656.3nm (C spectral line) respectively. Remember that the longer the wavelength the lower the refractive index and so the difference (n_F - n_C) is always positive. The early achromats had to have the converging lens possess less dispersion and a lower refractive index than that of the diverging lens.

Such an achromat cannot give a flat field and be free of astigmatism. To accomplish this glass used in the negative element must not only have a higher refractive index but a lower dispersion than the positive (converging) element. Such glasses did not exist until after the late 1880s or so when they were marketed by Schott in Germany.

(6) Lens Aberrations and their cure[54]

In the real world of glass lenses, in tracing the paths of rays through an optical system, use is made of Snell's law (sine a_1 / sine a_2 = refractive index) and the angles which the rays make with the optical axis and the glass surfaces. If the angles to the optical axis are small, they are termed ***paraxial rays,*** and it may be assumed that sine a = a, the angles being expressed in radians (π radians = 180^o, an angle of 25^o differs from its sine only by 3%, 20^o degrees by about 2%, see eq. 8 below). The theory is termed a ***first order theory*** or the ***Gauss theory,*** after its inventor. From a practical point of view the theory and its associated mathematics is adequate for determining the position of an image formed by a system of centered optics.

At this point it is necessary to recall that the sine of an angle (a), expressed in radians, may be expressed by a McClaurin series:

eq 7: Sine $a = a - a^3/3! + a^5/5! - a^7/7! \ldots,$

For angles below 1 radian (ca. 57.3 degrees), the series converges rapidly. During the years 1855-1856, Von Seidl developed his theory of the five aberrations and the conditions for their elimination. He included the 3rd term in equation 7 and developed his theory in terms of five corrective terms to be applied to the Gauss theory when considering the more oblique rays. Although the five aberrations can be realized by other mathematical means than the laborious trigonometric analysis of Von Seidl, it is nevertheless important in the history of optics.

S_1 = 0, No spherical aberration

As was implied earlier this means that for an object point on the optical axis all rays from that point will unite at a single point on the axis on the image side of the lens. Spherical aberration is proportional to the 3rd power of the lens aperture. It is impossible to eliminate spherical aberration in a single thin lens by any combination of radii, but it can be minimized. It can be successfully eliminated by combining two or more lenses so that the spherical aberration of the positive (converging) elements is compensated by that of the negative (diverging) ones, an approach similar and often used in conjunction with that used to eliminate chromic aberration. The approach works because spherical aberration varies as the cube of the focal length and thus changes sign with the latter. It is worth recalling that the Van Seidl approach does not consider chromic aberration at all.

S_2 =0, No Coma

Although with S_1 =0 all the rays from an axial point will focus at the same point, the focal points along the various rays may be different. Since lateral magnification or the height of the image compared to the object depends upon focal length, different magnifications will be produced for different circular zones about the optical axis. The result is a tear-drop-shaped image of an off-axis point object, each circular zone of the lens possessing a different focal length, with the image being the sum of the overlapping circles produced by each. If we consider an image point (y) located off the optical axis and its image (y') it can be shown that in the absence of coma:

eq 8: uy sine a = u'y' sine a'

Where (a) and (a') are the angles measured from their respective points of intersection with the optical axis and with each pair of angles being associated with a different zone of the lens until the edge of the lens is reached. The (u) values refer to refractive indexes. Since the lateral magnification (y/y') is constant in a coma free lens system (sine a/ sine a') must be a constant for all values of (a) and (a'). This is known as the ***Abbe sine condition***. Unlike spherical aberration, coma can be eliminated from a simple lens by proper choice of radii.

S_3 = 0 No Astigmatism

Astigmatism is associated with object points a considerable distance from the optical axis. It has been said that if coma is absent, it has in reality faded into astigmatism, a less serious fault. If S_1 =S_2 =S_3 = 0, the lens is said to be ***stigmatic,*** from the Greek word "stigma," meaning point. A pencil of light that fails to unite at a single point after refraction is said to be astigmatic. Although spherical aberration and coma are varieties of astigmatism the term is

restricted to apply to apply to point objects considerably off the optical axis. The result is that the image of an off axis point comes to two separate focal points each, instead of being a point is a short straight line with one being horizontal and the other vertical. In between the two focal points there is found a point where the two images combine to form a circular image called the ***circle of least confusion*****.** Astigmatism is eliminated by choosing a lens combination that brings the two images, i.e. those of the horizontal and vertical lines, together.

S_4=0 Image has no curvature of field

The image formed by a simple converging lens is not flat, but rather lies on a curved surface. Since curvature of field and astigmatism are closely related, their corrections go hand in hand, both are nearly proportional to the focal length, be they plus (converging) or minus (diverging) and virtually independent of the shape of the glass lens. The combining of positive and negative lenses in contact is of no avail, since both would have the same focal length and would cancel each other out. However both faults can be eliminated if the elements are separated. In the case of the positive and negative combination mentioned above, of the same focal length and made of the same glass, the image will be free of astigmatism, and curvature of field at any distance of separation and the combination will be converging if separated by a distance less than their individual focal lengths (see eq, 2a), it also should be mentioned that by the positioning of a stop in the lens system, the two astigmatic images can be made to curve in opposite directions and ***artificially flatten the field***. Such a procedure was the only one available up until 1886 when Schott made the new optical glasses available; hence the mention of stops being placed before the projection lens in the magic lantern literature.

S_5 = 0, Image **is distortion free**.

We are finally coming to the end!! A distortion free image is one that shows the image of a square in which the sides are not curved outward (barrel distortion or negative distortion) or inward (pincushion distortion or positive distortion). Distortion can be controlled by a suitably positioned stop. For a simple positive (converging) lens, a stop placed in front of the lens before the lens will produce negative or barrel distortion, if the stop is placed at the front focus the image will be free of distortion, or **orthoscopic.** The front focus is where the rays traced from the object cross in front of the lens. If the stop is placed behind the lens, it is known as a hind stop, and the distortion is positive or pincushion. For an image to be orthoscopic and form an undistorted image of a flat object, such as a lantern slide, the lens must be free of spherical aberration with respect to the position of the stop and its image. In separated two component systems the stop is placed between the two components. At this point you are probably hoping the author will stop and he soon will.

If the reader has survived to this point, it should be clear that lens design is a compromise, and with photographic objective lenses, the results, while very good, fall quite short of those predicted from diffraction theory. As the f# decreases, or the "speed "of the lens increases, performance drops off alarmingly as to what diffraction theory says is possible. I suspect that this is the reason why it is virtually impossible to obtain lens test data from manufacturers, either for camera lenses or microscope objectives.

(7) Point Projection

While point projection works best without any lenses, by removing the projection lens from a magic lantern, point projection can be achieved. A lantern of the author's with a 3.5" focal length condenser and a 200 watt FEV bulb achieved images magnified about 4 times. The condenser to slide distance was 16 inches, the condenser to screen distance was 52 inches, and the light was removed from the lantern and positioned 16 inches behind the condenser. Image quality was very poor. To achieve lens-less projection, you will need a lamp with a very small filament. The author used a 6 volt 18 watt SUN brand lamp with a half silvered spherical bulb removed from a pocket-sized Regent brand projector. A wood mounted slide of 3-inch diameter produced a 14-inch high image when held 14 inches from the lamp, with a screen to lamp distance of 5.5 feet. Moving the slide closer to the lamp enlarges the image, and you can make it as big and fuzzy as you please.

Acknowledgements

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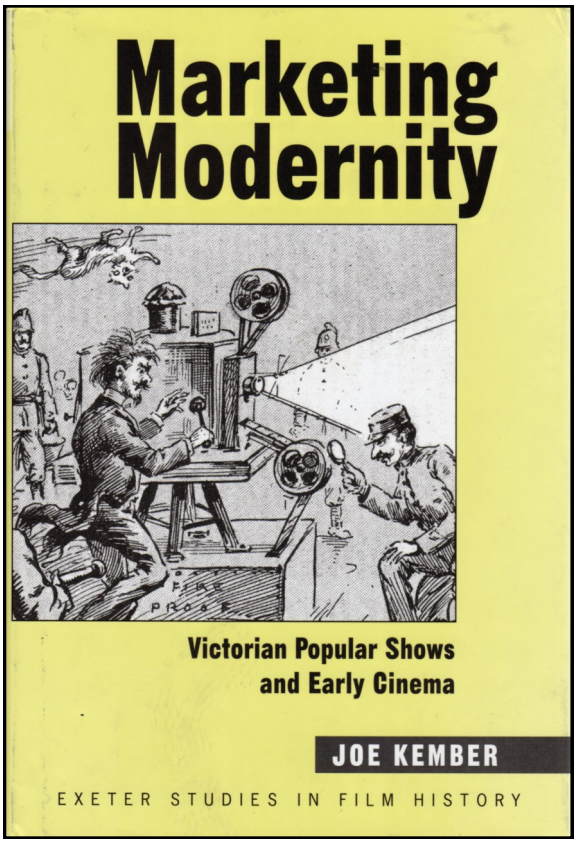


Joe Kember. 2009. *Marketing Modernity: Victorian Popular Shows and Early Cinema*. Exeter University Press, Exeter, UK. ISBN 978-0-85989-801-0. $85.00 (hardcover). 296 pages.

This book is a major new contribution to the history of magic lantern culture. Unlike many previous works linking magic lanterns to early cinema, Kember does not focus on the evolution of projection hardware, but instead describes various aspects of entertainment culture in Victorian Britain that set the stage for the emergence of cinema as a major form of visual entertainment. Two chapters in particular include a lot of material related to magic lanterns. Chapter 2, "Expertise and Trust: Popular Lecturing Traditions and Early Film," provides the best discussion I have seen of the world of traveling lantern lecturers in Britain, or anywhere else for that matter. Most accounts of the lecture scene focus on a few well-known figures like John L. Stoddard and Burton Holmes, mainly because they published their lectures, but Kember provides a much richer description of lecturers both famous and obscure. Chapter 3, "Knowing Better: Traditions of Showmanship and Early Film," describes the world of traveling showmen as entertainers, as opposed to educational lecturers, and how this carried over into early cinema practice. Some readers may find the writing a bit academic, but this book is recommended for anyone with a serious interest in magic lantern culture and its influence on early cinema.

The Research Page provides short summaries of recent academic research articles on magic lanterns and related subjects. This Research Page includes an eclectic assortment of articles from a variety of disciplines. For a complete bibliography of scholarly research on magic lanterns from the 1970s to the present, visit the **Magic Research Group** webpage (https://www.zotero.org/groups/magic_lantern_research_group).

Paul Carpenter. 2011. Mimesis, memory, and the magic lantern: What did the Knock witnesses see? *New Hibernia Review* 15:102-120.

In August 1879, several individuals reportedly witnessed the appearance of the Virgin Mary, alongside images of Joseph and John the Evangelist, on the side of the village church in Knock, County Mayo, Ireland. This event led to the church becoming an important Catholic shrine to the Virgin Mary. From the time the event occurred, however, skeptics questioned the validity of the apparition as a supernatural occurrence. One long-standing theory has been that the apparition was produced by a magic lantern projection. Several eyewitness accounts are consistent with the magic lantern theory, including descriptions of the apparition appearing as a circle of light, and reports that the figures in the apparition resembled statues that did not move. Carpenter argues that several lines of evidence support the presence of a magic lantern at Knock, although it is not clear whether the original event was a lantern projection. He reports that the Rev. Dr. Francis Lennon, a Professor of Mathematics and Natural Philosophy, conducted experiments shortly after the event to determine if the apparition could have been artificially produced, including by projection with a magic lantern. Lennon himself argued that it was unlikely the images on the church were produced by magic lantern projection, and instead argued for a rather implausible alternative—that the images were the result of some sort of phosphorescent paint having been applied to the wall of the church. Carpenter is not the first to write about the apparition at Knock or to discuss the magic lantern theory. Devout Catholics have tended to accept the apparition as real, whereas skeptics have often championed the magic lantern theory in books, articles, and web pages. There also is a scholarly book by Eugene Hynes (*Knock: The Virgin's Apparition in Nineteenth-Century Ireland*, Cork University Press, 2008) that includes a chapter on the magic lantern theory, although the focus of the book is the context of 19th century Irish culture in which the event took place. Carpenter's article provides evidence from eye-witness accounts that is consistent with magic lantern projection, but he leaves unresolved the question of how the original apparition was produced. Instead, he invokes Michael Taussig's interpretation of Walter Benjamin's notion of mimesis (Michael Taussig, *Mimesis and Alterity*, Routledge, New York, 1993) to suggest that it was the memory of Lennon's experiments with lantern projection shortly after the original event that merged with memories of the original apparition to give rise to the magic lantern theory. So the answer to the question, "What did the Knock witnesses see?" is still unclear.

John Tresch. 2011. The prophet and the pendulum: sensational science and audiovisual phantasmagoria around 1848. *Grey Room* 43:16-41.

This highly academic article juxtiposes two kinds of performance seen by audiences in Paris around 1848. The first was *The Prophet*, an opera by Giacomo Meyerbeer, which relied heavily on both visual and acoustical special effects. The second was the installation of Foucault's pendulum in the Pantheon. Tresch sees these public spectacles as manifestations of two trends in early 19th century French thought—the broad appeal of the fantastic, or phantamagoric, in literature and art, and the growth of Positivism and objective science. The boundaries between sensational art and entertainment and public displays of science became blurred as scientists relied on demonstrations of complex scientific apparatus to dazzle the public, and musical and visual artists relied on apparatus to provide spectacular audio-visual effects. Tresch sees early elements of both trends in Robertson's Phantasmagoria, which relied on optical tricks and spooky music to frighten and dazzle audiences, but took place in a venues decorated with both skulls and skeletons and various kinds of scientific apparatus. The history of the Phantasmagoria itself is only briefly addressed in this article, and the author ignores much of the research on the subject by magic lantern scholars, although he does mention work by Tom Gunning and Laurent Mannoni. In an odd error, he places Robertson's show in the first decade of the 18th century, when he means to say the last decade of the 18th and first decade of the 19th century.

Tom Gunning. 2009. The long and the short of it: centuries of projecting shadows, from natural magic to the avant-garde, pp. 23-34. In: Stan Douglas and Christopher Eamon, *Art of Projection* (Hatje Cantz Verlag, Ostfildern, Germany).

Tom Gunning's chapter, which was a major source for John Tresch's paper discussed above, provides a brief introduction to Robertson's Phantasmagoria. He begins by pointing out that the production of the phantasmagoria in a darkened room was very different from contemporary Western theater traditions, in which both the players on stage and the audience were illuminated. He describes the way in which visitors approached the venue for the show, passing through a room devoted to various kinds of scientific apparatus, demonstrations of electricity, tricks of a ventriloquist, and the disembodied voice of an "invisible woman." He goes on to describe the projection techniques used in Robertson's show and some of the slides that were shown. He discusses the use of the term "phantasmagoria" in various literary sources and the work of social critics such as Karl Marx and Walter Benjamin. He also compares the phantasmagoria to modern performances involving projected images, such as the films of Zoe Beloff that invoke images of 19th century "spirit"

photography. The chapter is part of a volume devoted mostly to modern projection art, and much of the historical material will be familiar to readers of this journal. There are a number of well-reproduced illustrations of Robertson's show, some of them also familiar from other sources, but others not so familiar. In an odd typographical error, the inventor of the phantasmagoria, Paul de Philipstahl (Paul "Philidor") is referred to in one paragraph as Philip Polidor, although his name is given correctly in another paragraph.

Karl D. D. Willis. 2011. A pre-history of handheld projector-based interaction. *Personal and Ubiquitous Computing*. Published online April 21, 2011 (DOI 10.1007/s00779-011-0373-5).

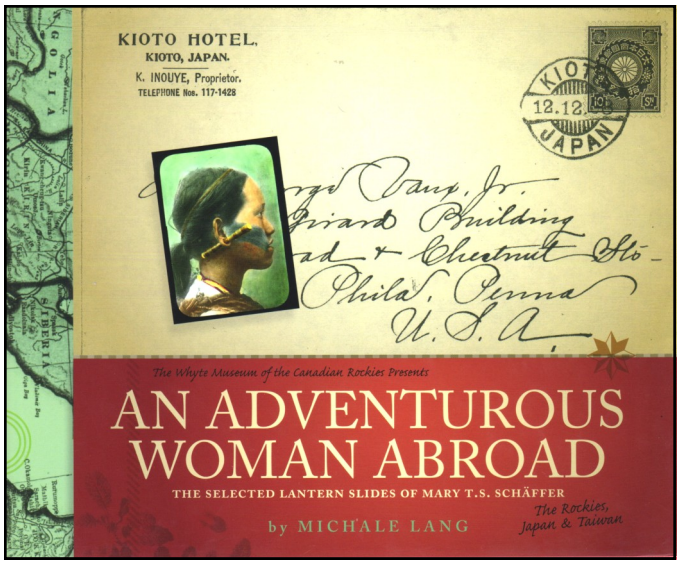
This interesting history of hand-held projection devices was published in an academic journal that most readers of this journal probably have never heard of and is aimed primarily at an audience concerned with computer-based digital projection. The author focuses on European examples of hand-held magic lanterns from the 18th and early 19th centuries, as well as Japanese *utsushi-e* performances using multiple wooden magic lanterns. The author describes many technical aspects of hand-held projection with these types of magic lanterns. Despite the somewhat obscure publication venue, the article will be of great interest to many members of our society. It is richly illustrated in color with photographs of lanterns and printed images of magic lantern shows, mostly from the collections of society members Jack Judson and Erkki Huhtamo.

Friedrich Tietjen. 2011. Loop and life: a false start into protocinematic photographic representations of movement. *History of Photography* 35:15-22.

This relatively short essay focuses on the work of Edweard Muybridge and Ottomar Anschütz, both of whom exhibited moving pictures at the Columbian Exposition in 1893, and in both cases, their efforts were commercial failures. Muybridge projected images of running horses and other subjects in his Zoopraxigraphical Hall, using a sort of projecting phenakistiscope. Anschütz presented moving images with his Tachyscope, another wheel-like device, which could either be used by single viewers or to project images. The author basically describes both of these devices as dead-end attempts to represent motion and argues that their main flaw was that images on a wheel or disk would endlessly repeat themselves, as would be true for a toy phenakistiscope or a zoetrope strip arranged in a continuous loop. This makes it impossible for the images to tell a linear story, something that was made possible by a strip of film showing images such as a train moving toward the viewer. In contrast to the disk-type projection system, a strip of projected film would not result in a train approaching the viewer and becoming larger, only to suddenly revert to its original tiny size in the distance.

Henning Schmidgen. 2011. 1900—The spectatorium: on biology's audiovisual archive. *Grey Room* 43:42-65.

This important article deserves a wider audience than the usual readership of *Grey Room*, an interdisciplinary journal of media, art, architecture, and politics. Written by a historian of science, the article tells the fascinating story of the evolution of projection techniques in the teaching of experimental physiology in the 19th and early 20th centuries, especially in Germany. Starting in about the 1860s, German experimental physiologists were much concerned with the concept of "Anschauung," or visual perception, as a key component of teaching physiology. A leading proponent of using visual aids in instruction was Johann Czermak at the University of Leipzig. In the late 1860s, he developed a projecting cardioscope using a bright light and a system of mirrors and lenses to project the image of a beating frog's heart onto a screen, allowing a lecturer to do a live demonstration while describing physiological processes. Czermak also coined the term "spectatorium" to describe a lecture hall fitted out for use of projected images, as opposed to an "auditorium" designed for listening to lectures. In that sense, the spectatorium was the forerunner of modern university high-tech lecture halls equipped for both digital PowerPoint projection and projection of opaque objects. Other German scientists, such as Carl Jacobj, perfected the art of projecting such live physiological preparations with innovations in lighting design, especially carbon arc lighting, and modifications such as placing a water tank between the light source and the specimens to avoid cooking the preparations. Another innovation was the use of rear-screen projection in several physiological institutes. This allowed for specimens to be prepared in a preparation room behind the lecture hall and then projected from that room onto a translucent screen for viewing by students in the lecture room. By the end of the 19th century, German optical companies, including Zeiss, Leitz, and Stoelting, were producing elaborately designed devices for opaque projection (episcopes) in scientific lecture halls, as well as devices that combined opaque and transparent slide projection (epidiascopes, universal projectoscopes). The article is well illustrated with some interesting pictures of preparations being projected in lecture halls and various kinds of projection apparatus. It addresses a neglected aspect of magic lantern technology and the way in which technology changed the nature of scientific instruction through the use of living "motion pictures" well before the appearance of cinema.



Michale Lang. 2011. *An Adventurous Woman Abroad: The Selected Lantern Slides of Mary T. S. Schäffer*. Rocky Mountain Books, Calgary, Alberta, Canada. ISBN 978-1-926855-21-9. $32.95 Canadian (hardcover). 276 pages.

This beautifully designed and illustrated book is a "must have" item for any collector with an interest in photographic lantern slides, and it will be special treat for our Canadian members. Based on a large collection of lantern slides and scripts in the Whyte Museum of the Canadian Rockies, the book tells the story of Mary T. S. Schäffer, who traveled throughout the Canadian Rockies in the early 1900s, taking photographs to be used in lantern slide lectures. She also traveled to exotic countries, including Japan and Taiwan, and slides from those trips are included in the book as well. The author is the Director and Chief Curator of the Whyte Museum, so is in a good position to make full use of the museum's collections.

Mary Sharpless (Schäffer) was born in 1861 in West Chester, Pennsylvania to a family of Quakers. She was well educated and took part in many family vacations to western National Parks in her childhood. In 1889, she married a Philadelphia physician and amateur naturalist, Dr. Charles Schäffer, and moved to Philadelphia. She and her husband visited the Canadian Rockies as tourists, traveling in relative comfort on the newly established Canadian Pacific Railroad. Early in her travels, the upper-middle-class Mary preferred comfortable accommodations and seldom ventured far into remote parts of the parks they visited, including the sumptuous mountain hotels in Banff National Park. In 1898, Mary and her husband took part in a Philadelphia Photographic Society expedition to Banff. Amateur photography was all the rage in the 1890s, and many photographers presented their work at society meetings as lantern slides.

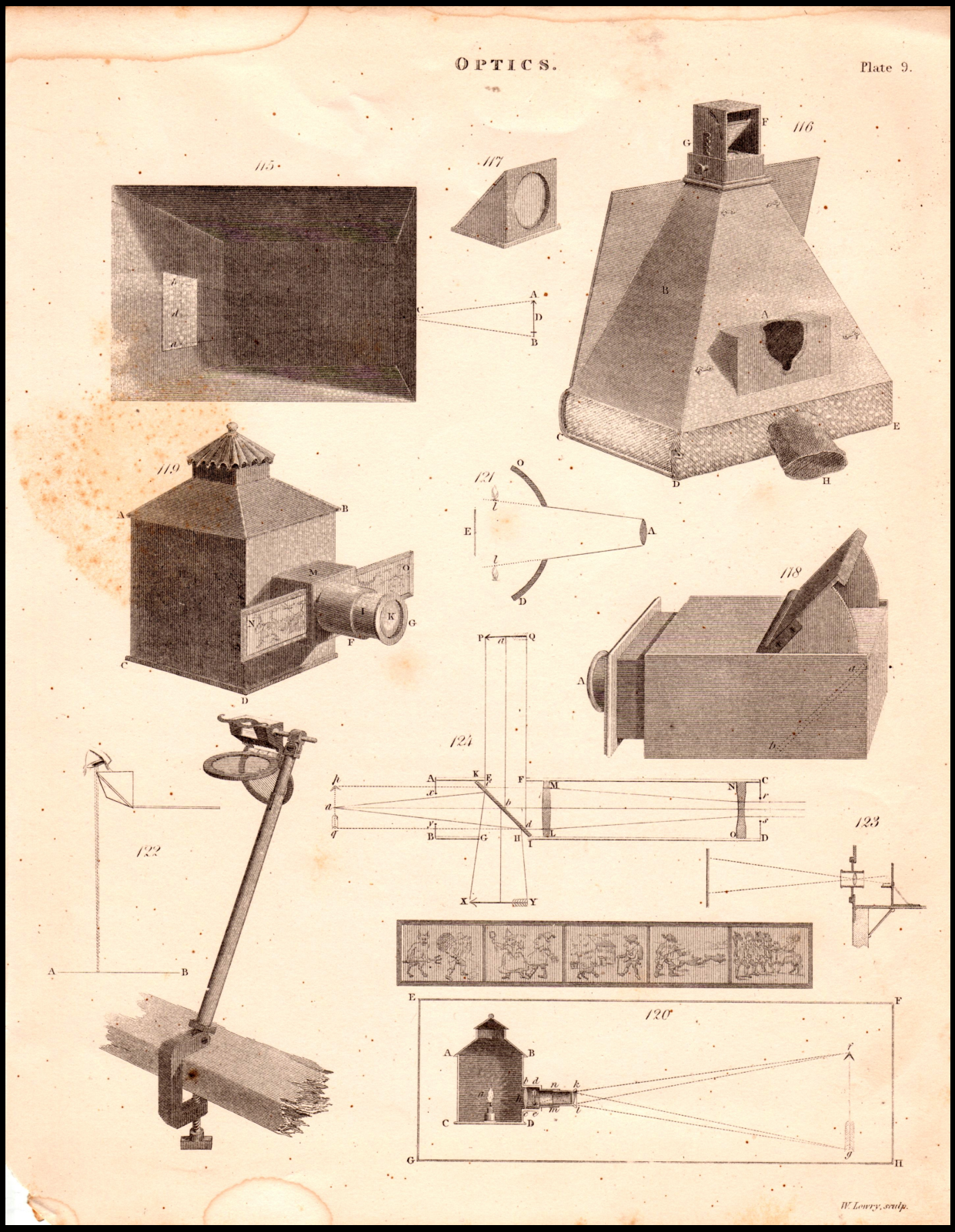
Mary took a particular interest in American Indians (now referred to as the First Nations in Canada), and her pictures included portraits of Indians from the Rockies in full tribal regalia.

After her husband died in 1903, Mary was left on her own and became more adventurous in her travels, going further afield in the Rockies and traveling to exotic locations in other countries. Using local guides, Mary ventured far into the wilderness of the Canadian Rockies, photographing scenery and people along the away and keeping journals of her travels. Eventually she published a book of travels, *Old Indian Trails of the Canadian Rockies* (1911). In the same year the book was published, she relocated to Banff, where she lived for the rest of her life (she died in 1939). She also married her principal guide, Billy Warren, some 20 years younger than she was.

Mary continued her travels and photography for many years and used her photographs to produce hand-tinted lantern slides that she presented in lectures. She presented lantern slide shows to promote tourism in the Canadian Rockies, and she gave shows to Canadian soldiers during the First World War. About 125 pages of this book are devoted to reproductions, mostly in color, of slides used in several lantern slide shows, with text drawn from Mary's original scripts now in the Whyte Museum. The slides are presented on black pages, so stand out as they would on a screen in a darkened room. Most of the slides are her own work, although she did purchase some slides from Byron Harmon and other Canadian photographers. There also are some slides by her third husband, Lonsdale Fonds. Most of the photographs are reproduced at about half or one-third page size, but some are full-page images. The final section of the book includes some very interesting lantern slides taken on a trip to Asia in 1908. Mary continued to be interested in indigenous people, and in particular, the Ainu people of northern Japan, who are ethnically distinct from other Japanese. This part of the book includes some beautiful photographs of people, mostly in rural areas, again accompanied by text from her original lantern slide script.

Everything about this book is well done. The photographs are well reproduced and the accompanying text brings these early lantern slides to life. The design and layout of the book are excellent, and the price is remarkably low for a book of this quality.

Stoney Indian from the Canadian Rockies. From an lantern slide by Mary Schäffer.



In the main feature article in this issue, John Davidson gives a detailed history of magic lantern optics.
Wells collection

Front cover: lantern slide of the nest of the Veery. Wells collection.

The Magic Lantern Society of the United States and Canada